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DEVELOPMENT OF A STORMWATER MONITORING PLAN AND GEOGRAPHIC INFORMATION SYSTEM AT BACK BAY, VIRGINIA

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INTRODUCTION

Back Bay is located in the southeast corner of the City of Virginia Beach, Virginia (Figure 1). It is the northernmost extension of the Albemarle, Pamlico, Currituck Sound estuarine system in North Carolina. This system is the second largest estuarine system in the United States. Back Bay was open to the Atlantic Ocean until approximately 1830, when the Currituck Inlet was closed by a storm. This event greatly reduced the bay's salinity to slightly brackish, causing a previously valuable oyster bed to be replaced by submerged aquatic vegetation (SAV), a freshwater fishery and an increased waterfowl population within a few years. (Weiland 1897; cited in Sincock et al. 1965). The closure of Currituck Inlet reduced lunar tidal action to a negligible affect, and with Back Bay's shallow average depth of 4.4 feet, it promoted frequent wind tides (seiches).

The Back Bay watershed's total area equals 104 square miles, which includes the bay's 39 square miles of open water (Priest and Dewing 1991). The ecology of the northern portion of the watershed is being threatened by urban development, induced by explosive growth in the human population of the city of Virginia Beach. Agricultural land use, comprising 21 square miles, is predominant in the southern portion of the watershed. Similar to large wetland areas such as the Great Dismal Swamp in Virginia, much of the land surrounding Back bay has been drained and converted to agriculture. In order to minimize flooding and maximize the area available for agricultural production, extensive ditch networks have been constructed to drain these fertile lands. Ditches directly drain into the larger creeks that ultimately drain into the bay. It is through this process that nonpoint source water quality problems have evolved from both agriculture and urbanization of the watershed.

Submerged aquatic vegetation (SAV), fisheries, and waterfowl populations in Back Bay have greatly fluctuated since the 1920s (Schwab 1991). Back Bay once provided an overwintering area for a large proportion of the Atlantic Flyway waterfowl and had highly productive SAV

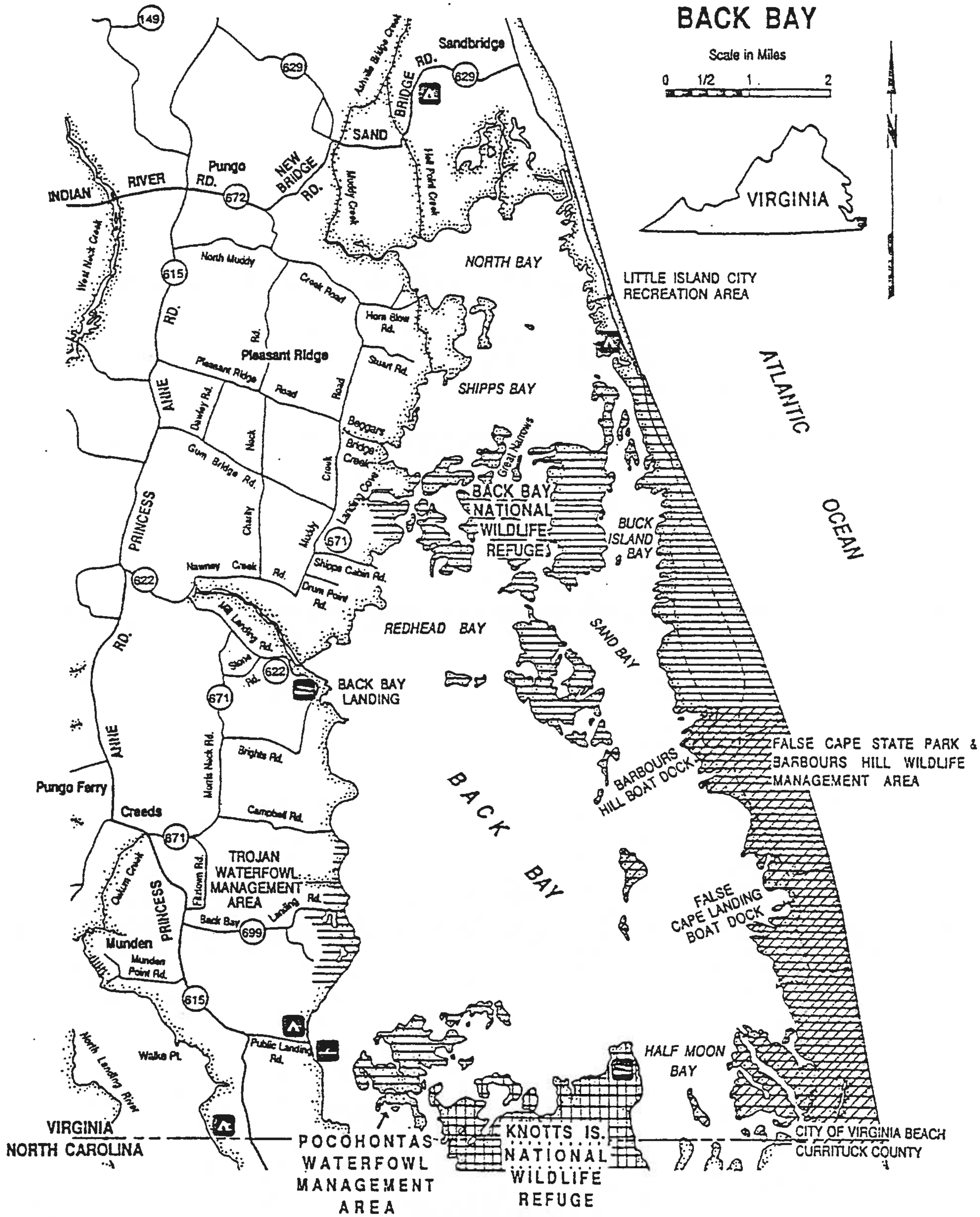

Figure 1. Map of Back Bay, Virginia.
(Source: Marshall, 1990)

beds. Currently, there is relatively little SAV in the bay (Schwab 1991), waterfowl use is minimal, and fish populations have also declined (Southwick and Norman 1991). The decline of the bay's natural resources is of major concern to a number of State, Federal and local government agencies, as well as several private conservation groups. This concern has resulted in several efforts to study the bay's water quality. Several theories attempting to explain this decline have resulted from these studies. The most prevalent factors believed to be contributing to the biotic declines in the bay are: 1) turbidity attributed to various land use practices including development and agriculture within the watershed (Alden and Priest 1991), as well as from past dredging activities (Sincock et al. 1965); 2) herbicide and pesticide runoff from agricultural fields, housing developments, and a golf course (USFWS 1991); 3) high nutrient levels from agriculture and failing septic systems from homes along the eastern border of the bay (Alden and Priest 1991); and 4) a gradual conversion of the bay from an estuarine to a brackish/freshwater environment (Rideout 1991). The increase in turbidity has been suggested as a major factor in the decline of SAV populations in the bay. Causes of increased turbidity are unknown, however, recent studies suggest that Total Suspended Solids (TSS) accounts for much of the variation in light attenuation (Carter & Rybicki 1991). Potential sources of TSS include dredging activity, low salinity, surface runoff, and wave-induced resuspension of bottom sediments. Relative contributions of these sources to the Back Bay system are not known.

The City of Virginia Beach initiated a salt water pumping operation in 1965. This operation began in the hope that increasing salinity would increase water clarity by flocculating suspended solids (Southwick 1989). It was believed that increased water clarity, and thus greater light penetration, would stimulate SAV growth. Although the pumping did raise the salinity in the bay. like so many other events (Table 1), failed to make a substantial contribution to water quality and SAV growth (Sincock et al. 1965). Following several pump equipment failures during the mid-1970's, the pumping operations were discontinued in 1987.

TABLE 1. Important historical events related to the water quality of Back Bay.

1600s	Open ditch drainage systems constructed in Back Bay watershed
1657	Old Currituck Inlet opens
1728	Old Currituck Inlet closed
1713	New Currituck Inlet opens
1828	New Currituck Inlet closed
1859	Albemarle and Chesapeake (A & C) Canal constructed
1890	Princess Anne Road causeway to Knotts Island constructed
1917	Great Bridge locks on the A & C Canal opened (dredging during 1914-19)
1920	Corey's Ditch constructed to mitigate blockage by Princess Anne Rd. causeway
1929	Bourn report completed
1932	Great Bridge locks on the A & C Canal closed
1933	Hurricane
1935	Dune stabilization of False Cape completed by CCC
1936	Hurricane
1938	Back Bay National Wildlife Refuge established
1955	Hurricane
1958	Back Bay-Currituck Sound Study initiated
1960	Hurricane
1961	Mackay Island National Wildlife Refuge established
1962	City of Virginia Beach incorporated
1962	"Ash Wednesday Storm"
1963	Filling of the Sandbridge Marshes initiated (completed in 1965)
1964	Eurasian milfoil likely introduced
1964	Back Bay-Currituck Sound Study completed (Sincock *et al.* 1965)
1965	City of Virginia Beach initiates saltwater pumping at Little Island Park
1974	Little Island pump shutdown and apparently not fully operational until 1978
1977	Little Island pump burned down
1978	Little Island pump replaced and operational until 1987
1982	Comprehensive Plan including "Green-line" adopted by City of Virginia Beach
1984	Mann management plan for Back Bay completed
1986	Hydrilla intentionally introduced
1987	Little Island pump terminated
1987	Albemarle-Pamlico (A-P) Estuarine Study initiated by EPA and NC
1990	Back Bay Ecological Symposium (Marshall and Norman 1991)

Back Bay has historically been valued as an outstanding wildlife habitat and recreational area. There are currently five State and Federally owned conservation areas within the Back Bay watershed drainage. The largest of these is the Back Bay National Wildlife Refuge, maintained since its primary acquisition in 1938 by the U.S. Fish and Wildlife Service (Service). The Back Bay Refuge, upon completing its acquisition phase, combined with the Mackay Island National Wildlife Refuge, will constitute 16 percent of the Back Bay watershed (Priest and Dewing 1991). This places the Service in the unique position as a major land holder within the watershed and obligates the Service to actively manage for the benefit of Service interests.

In 1991, the U.S. Fish and Wildlife Service initiated a study designed to quantify the extent of sediment contamination in Back Bay, as well as determine the toxicity of these sediments to SAV and amphipods. Some elevated levels of aluminum, magnesium, iron, and zinc were found in some areas, however, no other contaminants were measured at significant levels in the sediments, including pesticides, herbicides, and other organic compounds (USFWS 1991). Furthermore, significant toxicity of these sediments to aquatic biota could not be demonstrated through bioassay experiments.

Sedimentation and eutrophication of the bay are the focal issues that remain to be addressed. Ongoing studies, by the Virginia Water Control Board, the Virginia Department of Game and Inland Fisheries, and a private conservation group, are being carried out to quantify turbidity and nutrient levels primarily in the mainstem of the bay, and to a lesser extent in the major tributaries of the bay. However, the problems of sedimentation and eutrophication are similar in that both are pulse runoff conditions. Interval monitoring, like that mentioned in the studies above, only provides a static picture of water quality which may or may not capture the input pulse caused by storm events. Sediment and nutrient inputs from tributaries are the focus of the Service's Back Bay Initiative.

The initial objective of the Service's Back Bay Initiative will be to implement the first phase of a multi-year stormwater monitoring study to identify the main sources of sediment and nutrient inputs into the bay. A second objective will be to develop a Geographic Information System (GIS) database for tracking land use patterns and water quality data in the watershed. The use of GIS will support the analysis and identification of water quality problems related to land use. Moreover, GIS will be used to identify areas where the Service may be able to implement soil conservation practices, commonly known as Best Management Practices (BMPs), to be of the most benefit to water quality.

Geographic Information Systems are commonly regarded as mapping programs that store pictures or maps. Instead, GIS stores a database and is capable of sequestering information and formulating it into a geographic representation. The database concept is central to the GIS, thus separating it from computer mapping or drafting programs. GIS has been developed by geographers as a database management and analytical tool thatcan access any information that describes a point or area on a map such as latitude and longitude, property ownership, population, utility, or soil type. The extent of the data is limited only to that information that can be entered into digital form and spatially linked.

Methods

At the end of the first year of the stormwater monitoring program, the relative input of sediments and nutrients into Back Bay from its major tributaries will be assessed, and the tributaries contributing the greatest amounts of sediments and nutrients will be identified. Furthermore, seasonal variations in the magnitudes of these inputs will be assessed by sampling during winter, spring, summer and fall periods. Statistical relevance of this data will be established by sampling a minimum of three storm events per season.

Actual field sampling is measured using American Sigma (four model 1035's and three modified model# 702's) automatic water samplers. Sampling of water is automatically triggered during storm events by programming the samplers to initiate sampling when rainfall exceeds a predetermined value within a specified period. The rainfall/time trigger point for this quarter is set to 0.1 inches of rainfall within thirty minutes. Once sampling has been initiated, it will continue at regular intervals for the duration of the storm event. The sampling interval for the first phase is thirty minutes. Each sampler can hold up to twenty-four sample bottles, consequently allowing for a sampling period of 12 hours. Thus, real-time data is obtained in which sediment and nutrient inputs into the bay can be quantified throughout the course of individual storm events.

After a 15 milliliter (mL) aliquot is removed from each water sample for turbidity analysis, the remaining portion of each sample is composited and dispensed into previous prepared bottles for analysis. The samples are analyzed for the nitrogen series, the phosphorus series, total suspended solids, volatile suspended solids, fixed suspended solids and chlorophyll A. The analyses are being performed by a local contract laboratory.

The samplers have been placed at the mouths of the four major tributaries of the bay (Hell Point Creek, Muddy Creek, Beggar's Bridge Creek and Nawney Creek), as well as three points in the mainstem of the Bay (Sandbridge, Ragged Island and Cedar Island). These locations are shown in Figure 2. Both tributaries and mainstem stations will be included in this study in order to assess the relative contribution of sediment and nutrient inputs from tributaries, as well as from wind generated mixing of these materials during storms. Presumably, wind generated mixing in the mainstem of the bay may be significant in causing diminished water quality in the bay, although no studies in the past have attempted to compare the relative importance of these two factors.

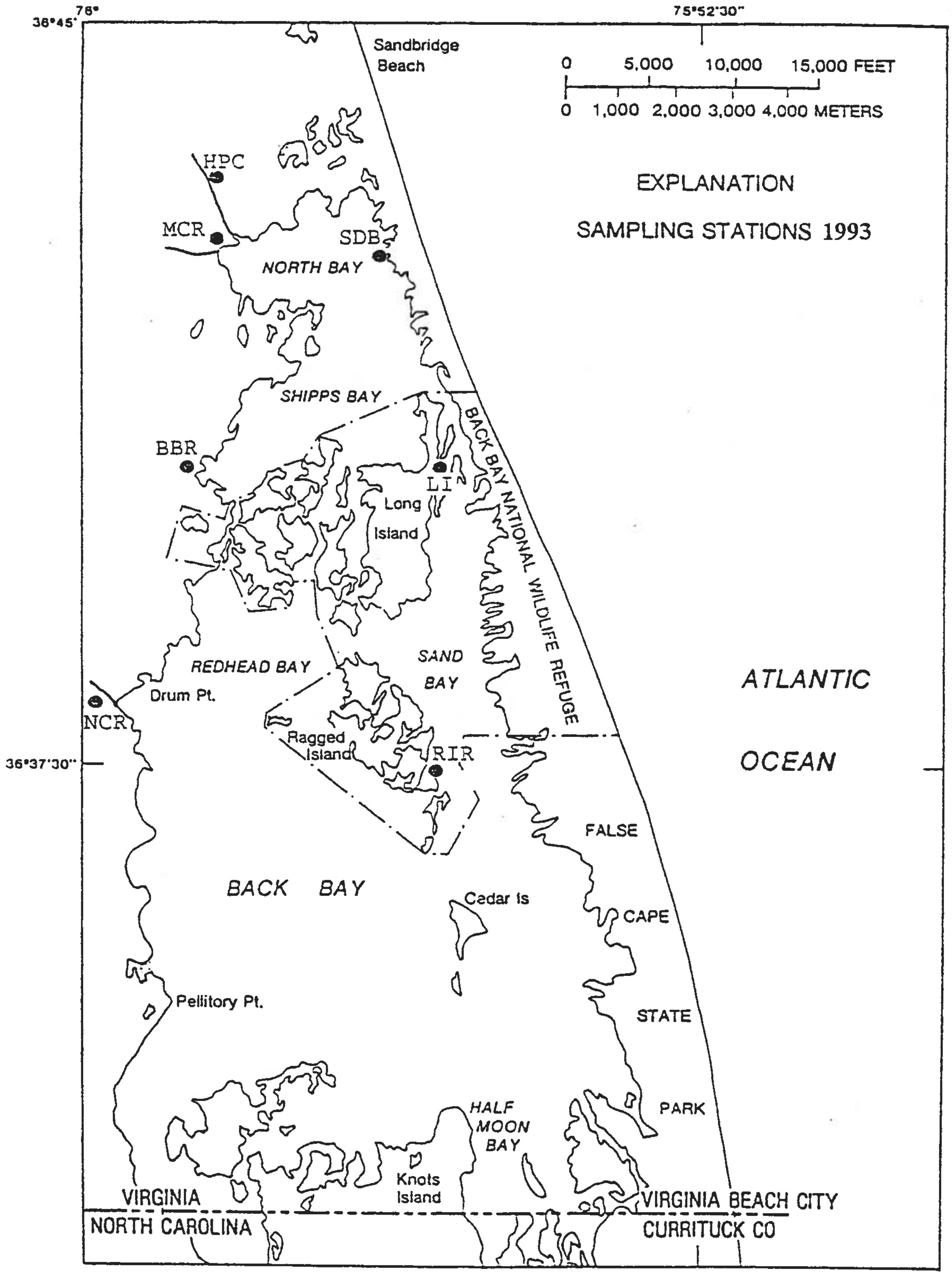

Figure 2. Map of Back Bay showing sampling stations for July 1987 (numbered stations) and April 1988 (stations with letters). (Source: Marshall, 1990)

The GIS is an ideal tool for the Back Bay Initiative because of its capability to compile information on vast areas with many facets of analysis. GIS analysis begins with obtaining the computer software that will perform at the level the project demands. In the Service's Virginia Field Office it was determined that a Personal Computer (PC) version of ARC INFO© GIS would suit the Service needs. It was predetermined that digitizing information was not going to be possible with a limited staff, therefore, data acquisition is the number one priority. There is not a single depository for GIS data in Virginia so the first step is to find out who possesses what data for the Back Bay watershed. From the list of available data, the project manager will decide what data coverages to obtain. The data coverages needed for analysis of watershed inputs for Back Bay include:

hydrology	land use	transportation routes
hydrography	soil type	political boundaries
topography	soil loss rates	watershed boundaries
census	wetlands inventory	sub-watershed boundaries
SAV coverage	vegetative cover	water quality study sites

If these coverages can be obtained in the 1:24,000 scale it will be the basis for an accurate GIS database. There are few data coverages in the 1:24,000 scale for the Back Bay watershed. City and State agencies are in the process of digitizing information for Virginia at this scale, but have not completed this task for the Back Bay area. Further investigation have located more coverage data available at the 1:100,000 scale. Hydrography and transportation route coverages have been obtained from the U.S. Geological Survey. Satellite imagery from the North Carolina Center for Geographic Information and Analysis (NCCGIA) was determined to contain a number of the coverages for the project. The value of this data to the project has not yet been determined. The size of the data files exceed the current storage capacity of the GIS platform computer at this time. Upgrades to the machine are planned but have not been possible due to budget and staff time constraints.

Conclusions

The logistics of the stormwater monitoring project thus far have proved to be more challenging than was expected. The seven sample sites in Back Bay often receive isolated thunderstorms during summer, and because of the distance between sites may not trigger all of the sampler units. The field office is approximately 70 miles from Back Bay. This distance makes it difficult to determine each sampler's program status, whether the program is running or still awaiting a sufficient rainfall amount. It would be beneficial to employ some type of remote sensing device, maybe as simple as one person from the Refuge checking each sampler following rain events. Other problems which have occurred in the early stages of the field sampling consist of programming errors, damage to sample intake tubing (by boat propeller) and battery failures.

At the conclusion of the monitoring program the following information will be obtained: 1) levels of turbidity in Back Bay and its tributaries during storm events, 2) inputs of sediments and nutrients into the bay during storm events, 3) the relative importance of inputs of this material into the bay via tributaries versus wind-generated mixing of bottom sediments in the mainstem of the bay, and 4) the tributaries responsible for the greatest inputs of sediments and nutrients into the bay. This data will also be incorporated with the data obtained at regularly scheduled intervals by others groups involved in water quality monitoring in the mainstem of the bay, allowing us to assess the impact of individual storm events on the bay's water quality in the context of the normal water quality conditions that exist there.

GIS database development will be in the data acquisition phase until upgrades can be made to the GIS hardware. It is undetermined at this time when the actual GIS database for Back Bay will be completed. The use of GIS could be an immense aid to targeting nonpoint source inputs and locations of BMP programs in the next phase of the Back Bay Initiative.

Once the tributaries contributing the greatest amount of sediment and nutrient inputs into the bay have been identified, they will be targeted for more intensive sampling efforts in subsequent years of the monitoring program. A proposal for this work, which will be carried out in the third and fourth quarters of FY 1994, will be submitted next year. This intensive monitoring will also be coupled with pilot BMP programs on both private and Service lands. At the conclusion of the study, definitive data on the efficacy of BMPs at enhancing or protecting water quality in a variety of settings will be available for use in watershed management decisions.

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